

CHAPTER I

INTRODUCTION

1.1 OBJECTIVE

The objective of this handbook is to provide the designer of facilities for handling explosive material with procedures for design of suppressive shields and a basis for deciding whether suppressive shields are cost effective alternatives to other protective systems.

1.2 SCOPE

This handbook presents procedures for design, analysis, quality control and economic analysis of suppressive shields. A suppressive shield is a vented steel enclosure which controls or confines the hazardous blast, fragment, and flame effects of detonations. Such shields must meet the requirements of Ref. 1-1 for protective barricades or operational shields to provide safety in loading munitions as well as munitions modification, renovation, and demilitarization.

Suppressive shields are but one option for providing protective systems. Reference 1-2 presents methods for design and construction of conventional reinforced concrete protective facilities. The information contained herein supplements Ref. 1-2 and provides procedures for evaluation of economic factors concomitant to the use of suppressive shields. Suppressive shields should be used where they provide cost effective alternatives to conventional facilities or provide additional benefits. References 1-3 through 1-7 provide the user of this handbook additional technical and regulatory guidance on explosive safety procedures.

The Department of Defense Explosives Safety Board has approved five basic suppressive shield designs for use in

hazardous operations. This handbook presents the design details of these approved shields with engineering guidance on their selection and modification to meet operational requirements. In addition, techniques are presented for the design of new shields for cases where existing safety approved shields will not meet requirements. Proof test and safety approval procedures are also included.

1.3 BACKGROUND

Suppressive shields are a relatively new concept for providing protection to the area surrounding hazardous operations in munitions plants. At present, the protection methods most commonly used are

- Wide dispersal distances between hazardous operations.
- Reinforced concrete barricades.

The hardwall concrete concept is designed to withstand the anticipated blast effects. Concrete cubicles typically used to protect hazardous operations have one side and/or the top open and the blast is not confined on the open sides. Neither method will contain all the fragments generated by a detonation.

Since a suppressive shield is a complete enclosure, it will

- Contain all fragments from a detonation.
- Attenuate blast overpressure in all directions to a safe level at a prescribed distance.
- Reduce the diameter of the fireball.

Suppressive shields are designed for quick erection and modification and to provide the maximum degree of protection

at minimal cost. Under normal service conditions, the shields are long lived and maintenance free. Other attractive advantages are that suppressive shields can provide improved personnel safety, lend themselves to rapid plant conversion, and can reduce real estate needs and equipment costs by reducing quantity-distance requirements. Through reduction of the structural loads on the building housing the hazardous operation, the use of suppressive shielding will result in a reduced building cost. In addition, suppressive shields will minimize downtime and equipment/facility restoration costs by confining the destructive effects resulting from accidental detonations.

1.4 ORIGIN AND DEVELOPMENT OF THE SUPPRESSIVE SHIELD CONCEPT

Concepts similar to suppressive shields have been used in the past to provide various forms of protection. For example, closed cubicles have often been used to completely confine detonation effects in testing with explosives, and homogeneously vented blast mats have been used in quarries and construction blasting. However, a technology base for systematic, scientific design of homogeneously vented structures was not available prior to the development of suppressive shield technology.

Early investigation of protective measures for the 4.2-inch white phosphorus mortar projectile by Edgewood Arsenal during 1968 resulted in the initial concept for suppressive shields. From these early tests, data were obtained to design several prototype structures.

A small cubical test fixture uniformly vented on five sides was designed to contain fragments and provide controlled venting of product gases from the detonation of a 4.2-inch white phosphorus mortar projectile. Successful testing with this 4-foot cubical led to the decision to apply the concept

to a portable shield for use in explosive ordnance disposal. Edgewood Arsenal, working with the NASA National Space Technology Laboratories, designed, fabricated, and tested the cylindrical shield shown in Fig. 1-1 at Dugway Proving Ground, Utah. The shield is nominally 5 feet in diameter and 5 feet long. It is uniformly vented on the cylindrical surface and at both ends. The shield is constructed with an interior layer of nested angles covered with a double layer of perforated sheet steel. All members are separated sufficiently to allow gas flow through the walls but not far enough to permit fragments to pass between structural members. Structural grade steel is used throughout. Successful tests with a maximum charge weight of 5 pounds of C-4 were considered to verify the concept in general. Additional tests were conducted using up to 20 pounds of C-4. Test data are reported in Refs. 1-8 and 1-9.



Figure 1-1. Early Model Suppressive Shield

These early tests indicated the feasibility of suppressive shielding for hazardous munitions handling operations, and under the direction of the Project Manager for Munitions Production Base Modernization and Expansion, an extensive manufacturing technology project was undertaken by Edgewood Arsenal to design and proof test several prototype structures and to develop a technology base for suppressive shield design. This handbook is one of the results of that effort.

The design procedures and analytical techniques presented herein are the result of extensive testing of both scale model and prototype structures. This work was the cooperative effort of

- Ballistic Research Laboratories, which was tasked with major efforts in the areas of blast and fragment definition, blast and fragment suppression, fireball definition, structural analysis, and shield testing.
- NASA National Space Technology Laboratories and Dugway Proving Ground, which performed testing of suppressive shields fabricated as part of the hardware development program. Extensive instrumentation was used to record blast pressure data and structural response data for verification of predictive analytical techniques.
- Naval Surface Weapons Center (formerly Naval Ordnance Laboratory), which provided blast codes for defining gas pressures inside suppressive shields.

- Southwest Research Institute, which provided contractual support in all analytical development areas and developed scale model laws for defining the blast pressure attenuation outside of suppressive shields.
- Huntsville Division, Corps of Engineers, which identified and developed current design techniques and conducted numerous design investigations in support of the Group 3 and 81-mm suppressive shields, including the preparation of construction specifications and engineering drawings.
- AAI Corporation which provided contractual support to develop shield penetrations for utility lines, vacuum lines, and environmental conditioning ducts.

1.5 USE OF THE HANDBOOK

The designer of a facility for munitions loading, maintenance, modification, renovation, or demilitarization must perform a hazards analysis of each operation and determine which operations involve potentially catastrophic Category III or IV hazards; see Table 1-1. The facility design must provide adequate safety for these hazardous operations. It may be that conventional protective barricades with appropriate separation distances or suppressive shields can be used, or that the operation can be isolated by separating it from other parts of the facility using quantity-distance specifications in Ref. 1-1. All safety considerations being equal, the decision as to which method will be used is based on economic factors. An economic analysis of alternative methods of protection must be performed considering facility, real estate, and equipment costs as well

Table 1-1
HAZARD LEVEL (Ref. 1-3)

Category	Hazard Level	Comment
I	Negligible	Will not result in personnel injury or system damage
II	Marginal	Can be counteracted or controlled without injury to personnel or major system damage
III	Critical	Will cause personnel injury or major system damage, or will require immediate corrective action for personnel or system survival
IV	Catastrophic	Will cause death or severe injury to personnel or system loss

as maintenance, operation, useful life, replacement, and renovation or modification costs insofar as they can be estimated.

In order to evaluate these economic factors, the designer must develop facility concepts using alternative methods of protection. He will use Ref. 1-1 for quantity-distance considerations, Ref. 1-2 for conventional reinforced concrete cubicles, and this handbook for suppressive shields. Costs will be estimated and compared over the facility life to determine the most economical mode of protection.

A major factor which must be considered in deciding which form of protection to use is the requirement for approval of the facility design by Department of Defense safety offices. If the designer can adapt one of the safety approved suppressive shields, either directly or by modification, and support the adaptation with proven, accepted analytical techniques, he can reasonably expect that the safety offices will approve his design. The designer should, therefore, begin development of a facility concept which employs suppressive shields using the safety approved shields which are described in more detail in Chapter 2 and Appendix A of this handbook.

Safety approved suppressive shields should meet most requirements by using the shield as designed or with slight modification of the shield dimensions. Facility safety approval will not be jeopardized by a modified shield if charge weight to volume ratio is maintained, the scaled distance to the shield wall is not reduced, and the shield maximum rated charge weight is not exceeded. When a modified safety approved shield design is proposed, it would be prudent to submit the modified design for approval prior to committing the entire facility concept to the modified shield application.

In submissions of proposed new shield designs or significant modifications to previously approved designs, documentation should summarize test results and analytical procedures which demonstrate the claimed level of protection to operators

or to the general public. The documentation should also show, if appropriate, that this level at least equals the protection provided by existing explosives safety standards applicable in the absence of such engineered safeguards as suppressive shields or any other type of explosion-resistant construction.

In exceptional situations where no safety approved shield can be made to fit a desired application, a new shield must be designed. The procedures for obtaining safety approval of a new shield design are described in Chapter 2. Chapters 3, 4, 5, and 6 provide the guidance needed to design a new shield. Hazardous environments resulting from internal and external airblast, fragmentation and fireball phenomena are presented in Chapter 3. Information contained in that chapter is used to determine venting requirements, airblast loads on the structure, and protection required to defeat fragments.

Structural behavior is addressed in Chapter 4. Typical construction material physical properties, ranges of structural response, structural failure modes, and acceptable damage levels are discussed. Information presented in Chapter 4 is a guide to the physical properties of the materials to be used in the structural analysis of suppressive shield designs. This chapter also includes guidance for determination of acceptable deformation limits.

A suppressive shield is usually designed with the maximum allowable venting which will meet blast overpressure suppression requirements. Then, using the structural design and analysis methods of Chapter 5, the structure is designed to have sufficient strength to withstand the pressure and fragmentation loads. Each suppressive shield installation will have specific requirements for utility penetrations, doors for personnel, equipment and products, and so on. Guidance on the provision of acceptable structural details such as these is presented in Chapter 6. Information on structural details which have been successfully proof tested is also contained in Chapter 6.

Once a shield design which meets blast, fragment, and flame suppression requirements has been achieved, its cost can be estimated and the data used in an economic analysis to determine the cost effectiveness of the design. The economic analysis of alternative facility concepts is a complex process which is unique to each facility. A completely general procedure suitable to analysis of all facilities would be so complicated that it would be useless. However, this handbook would be incomplete if the vital element of economics were ignored. Economic analysis of protective systems is discussed in Chapter 7, and two examples of economic analyses of facilities where suppressive shields were considered are presented as Refs. 7-5 and 7-6. One example is a melt-pour operation for 105-mm projectiles. The other is for a load, assembly, pack (LAP) operation with improved conventional munitions (ICM). These two examples illustrate the many factors that must be considered, show the magnitude of detail required, and can be used as a guide for other analyses.

It was demonstrated during the testing of suppressive shields that the strength of welds and concrete components is often the determining factor in the overall strength of a shield. Therefore, suppressive shield design packages must include specifications for assurance of the quality of concrete and the strength of welds, as well as basic design and material specifications. Guidance on quality assurance is contained in Chapter 8.

1.6 REFERENCES

- 1-1 Safety Manual, AMCR 385-100, Hq. U.S. Army Materiel Command, Alexandria, Va., Latest Edition. (U)
- 1-2 Structures to Resist the Effects of Accidental Explosions, TM5-1300, Department of the Army Technical Manual, NAVFAC P-397, Department of the Navy Publication, AFM 88-22, Department of the Air Force Manual, Washington, D.C., June 1969. (U)
- 1-3 System Safety Program for Systems and Associated Subsystems and Equipment Requirements for, Mil Std 882, U.S. Government Printing Office, Washington, D.C., 15 July 1969. (U)
- 1-4 Ammunition and Explosives Ashore, Department of the Navy Publication, OP-5, including Volume I, NAVSEA OP-5/1 "Safety Regulations for Handling, Storing, Renovation and Shipping", Volume II, NAVORD OP-5/2, "Storage Data", Volume III, NAVSEA OP-5/3, "Advance Bases", and all revisions thereto. (U)
- 1-5 Explosive Safety Manual, AFM 127-100, Department of the Air Force, Washington, D.C., 2 December 1971. (U)
- 1-6 Ammunition and Explosives Safety Standards, DOD 5154.4S, Department of Defense, Office of the Assistant Secretary of Defense (Installations and Logistics), March 1976. (U)
- 1-7 Shields, Operational for Ammunition Operations, Criteria for Design of, and Tests for Acceptance, Mil Std 398, U.S. Government Printing Office, Washington, D.C., 5 November 1976. (U)
- 1-8 Tanner, W.S. and Warnicke, C.H., Support Test for the Fabrication and Test of a Suppressive Shield for a Naval Ordnance Disposal Facility, DPG-DR-74-304, US Army Dugway Proving Ground, Dugway, Utah, December 1973. (U)
- 1-9 Warnicke, C.H., Added Support Tests of the Suppressive Shield for Naval Ordnance Disposal Facility, DPG-DRI-74-313, US Army Dugway Proving Ground, Dugway, Utah, September 1974. (U)